

MONTHLY WEATHER REVIEW

Editor, EDGAR W. WOOLARD

VOL. 66, No. 10
W. B. No. 1251

OCTOBER 1938

CLOSED DECEMBER 3, 1938
ISSUED JANUARY 30, 1938

THE 1937 FREEZE IN CALIFORNIA

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[Weather Bureau, Pomona, Calif., October 1938]

The California citrus industry ranks second to petroleum as a basic source of wealth in the State. During the past 10 years it has returned to the State an average of \$103,000,000 per year. The value of the crop delivered to the markets averaged \$144,000,000 per year during the same period, an average of \$41,000,000 per year being paid to the railroads for freight and refrigeration. Returns to the State in 1930 were \$135,000,000 and the delivered value of the crop was \$175,000,000. In 1929, a large crop year, the bill for freight and refrigeration was \$54,000,000. The industry furnishes livelihood for 200,000 people in California, only half of them growers and their families, and is the principal support of many cities and towns in the fruit-growing districts.

More than one-half of the \$41,000,000 annual freight bill is said to go directly to railroad labor for wages. Production of lumber and nails for boxes, paper wraps for the fruit, fertilizer, pest-control, and frost-protection supplies for the orchards employ other thousands. In 1937 the industry spent \$30,000,000 directly as wages to labor, divided roughly, \$23,000,000 in the groves and \$7,000,000 to packing-house workers. Orchard supplies, including fertilizers, water, pest-control, and frost protection, cost \$32,000,000 and packing-house supplies \$10,000,000.

Crop failure from any cause spells disaster to whole communities and materially affects the prosperity of people far distant from California. Crop failures also result in higher prices for both California and Florida fruit to the consumer, the same amount of fruit costing many millions of dollars more than in years when fruit supplies are plentiful. During the earlier history of the citrus industry, before the development of orchard heating, not only the crops but the trees were subject to constant threat of damage or destruction by low temperature.

The climate of citrus growing sections in California is subtropical in general, but there are marked climatic differences between different districts. In interior districts most of the groves are located on the slopes of the lower foothills, but near the ocean there are large acreages located on almost level ground. Early experiences taught the growers not to plant citrus trees on the lowest ground in interior districts, although recently more and more plantings have been made in the colder sections, with reliance on orchard heating to prevent frost damage. Better soil and lower irrigation costs on the lower ground offset to some extent the greater costs of frost protection.

Frost protection¹ through orchard heating began in California about 1897, when a few growers began to burn

coal in crude baskets made of chicken wire hung in trees. Protective methods improved and acreage equipped with heaters increased slowly until about 1913, and more rapidly thereafter. A survey made during the winter of 1937-38 showed 92,000 acres, or 29 percent of the total California citrus acreage, equipped with orchard heaters, requiring 2,860 carloads of oil for one filling. Oil storage tanks built exclusively for orchard heater oil in the citrus districts had a total capacity of more than 86,000,000 gallons.

Damagingly cold periods in California citrus districts are divided into two classes, frosts and freezes, but the classification of individual cold periods is sometimes difficult. True frosts are quite local in character, low temperatures being due mainly to radiational cooling after sundown. Range between day and night temperatures usually is large, sometimes as much as 60° F., strong temperature inversions build up during the night, and orchards located on hillsides are much warmer than those on the valley floor. Due to the strong temperature inversions near the ground, any wind of more than 4 miles per hour will cause an increase in surface temperature as a result of the mixing of relatively warm air at moderate elevations with the colder air in the orchards. Orchard heating under such conditions is very effective. Temperatures as low as 20° F. have been registered in citrus groves during purely local frosts.

Freezes are due mainly to the influx of great masses of cold air from the north or northeast, although radiational cooling after sundown also is an important factor. Freezes are more general than frosts, although in some small areas severe damage is usually prevented by wind, the effects of local topography, or proximity to the ocean. Diurnal temperature range is small, temperature inversions weak and shallow, and orchards in the foothills often are colder than those on the valley floor. Although extremely low temperatures seldom occur when wind continues steadily all night, the effectiveness of night winds in raising or preventing a fall in temperature usually is slight, due to weak temperature inversions. Maintenance of safe temperatures in the orchards through orchard heating usually is very difficult during freezes, due to air movement and weak inversions. Although local frosts cause some damage to citrus crops practically every winter, severe freezes occur only at intervals of 10 to 15 years. So disastrous have been the effects of past freezes that they stand out prominently in the history of the citrus industry.

While fragmentary accounts of early freezes have come down through the years, little or nothing is known of temperature or meteorological conditions accompanying

¹ See U. S. Department of Agriculture Farmers' Bulletin 1588, Frost and the Prevention of Frost Damage, for detailed information regarding frost protection methods.

them. In December 1891 a "great disaster" was reported, "preceded by a Santa Ana wind the like of which has never been seen before or since." Trees were described as glowing with phosphorescence, and "balls of fire leaped from tree to tree."² The winter of 1897-98 also is said to have been extremely cold. *Almanac in Arizona*.

On January 6, 7, and 8, 1913, occurred "the heaviest freeze since 1898," breaking all records for low temperature at a number of places in the State. The lowest temperature at Los Angeles equalled the previous record, and at San Diego a 64-year record for low temperature was broken. This freeze is the first about which there is any detailed meteorological information, although accurate orchard temperature records are almost entirely lacking.

The next freeze,³ which occurred, January 19 to 24, 1922, was not so severe as that of 1913, but caused great damage to both fruit and trees. The crop was reduced by approximately 20,000 carloads, resulting in a loss of freight revenue to the railroads of about \$10,000,000. Many individual growers not only lost all their fruit, but their orchards as well, although due to increased prices received for marketable fruit, the total return for the crop to California was only \$12,000,000 less than for the previous season. Orchard heating proved so successful during this freeze that a great increase in protected acreage followed.

Another freeze occurred in 1924, but its severity was much less than the freezes of 1913 and 1922. On December 9 to 15, 1932, an extremely heavy freeze occurred in Sacramento Valley citrus districts, in the northern part of the State, with orchard temperatures as low as 10.5° F. registered in the coldest groves, but it failed to reach the southern part of the State. A series of unusually mild winters followed up to and including the winter of 1935-36.

On the basis that severe freezes had occurred in the past every 10 to 15 years, fruit growers were warned repeatedly in published articles and at public gatherings that the mild weather of 1936 should not cause them to relax their vigilance, and that a severe freeze actually was overdue. Weather Bureau surveys had shown an alarming deficiency in orchard heater fuel storage facilities for carrying through a freeze, and every possible effort was made to acquaint the public with the seriousness of the situation. The danger was strongly emphasized in 9 different articles published in grower magazines as well as in frequent newspaper articles, and also was brought directly to the attention of growers and packing-house managers at more than a hundred meetings called to discuss orchard heating problems. These efforts resulted in an increase of nearly 20,000,000 gallons in oil-storage-tank capacity in the citrus districts, but statistics showed total heater oil storage to be still far short of minimum safety requirements. Officials of cooperative purchasing organizations charged with the responsibility of securing fuel for the growers therefore awaited the inevitable freeze in a far from tranquil state of mind.

The month of November 1936 was warm, with but one light frost and only light scattered orchard heating for lemons in one small area. Light to moderate frosts were frequent during December, with some orchard heating necessary on 5 nights. From the night of December 31 to the night of February 1 moderate to heavy frost occurred at some point in the citrus growing districts on all but two dates.

The first definite indication of an impending freeze was noted on the weather chart for January 4, and advisory warnings were given to packing-house managers. On January 5 packing-house managers were urged to fill up all orchard heater oil storage tanks and to make all other necessary preparations for a freeze. This warning was amplified on the 6th and given wide distribution to railroads, oil companies, etc. A severe freeze, comparable to the freeze of 1922, was forecast.

Supplies of orchard heaters in Pacific Coast warehouses were exhausted within a few hours after the first warning was made public. Many orchards, including one owned by the State of California at Whittier, were protected throughout both January freezes with heaters purchased, transported to the groves and filled with oil between the time of the first warning and the beginning of the first freeze. Wherever possible mature fruit was hurriedly picked from trees and hauled to packing houses, although in Tulare County and some other localities fruit could not be picked because of rain which immediately preceded the freeze.

A vigorous low-pressure area centered over northwestern Washington on January 4 moved rapidly south-southeastward, reaching northern Arizona on the evening of the 6th, bringing moderate to heavy rains to all of California. Cold polar-continental air followed in its wake, reaching northern California on the morning of the 7th and the Imperial Valley on the night of the 8th. The only citrus districts to feel the effects of the freeze on the night of the 6th-7th were those in the Sacramento Valley. Temperatures there held up well until morning, but dropped to 23° F. between 5 a. m. and sunrise. The freeze spread to the San Joaquin Valley on the following night and began to be felt in all southern California districts except the Imperial Valley, which was not reached until the night of the 8th-9th. Generally speaking, the night of the 8th-9th was the most severe of the entire cold period, although the freeze continued until the night of the 10th-11th, and temperatures in some districts were as low on the 9th-10th as on the preceding night. Snow which fell in the Redlands district on the night of the 6th remained on the ground in foothill orchards until the 11th. Notes on the individual nights of this freeze are given below for different districts.

January 6-7, 1937

Sacramento Valley district.—Clear; strong north wind slackened between 5:00 and 7:00 a. m. with rapid temperature fall from 27° to 23°. Heavy firing for lemons began about 11:30 p. m.

January 7-8, 1937

Sacramento Valley district.—Ice on puddles increased in thickness all day. Clear; strong northerly wind all night, despite which the temperature fell to 18° in spots. Heavy firing began at 11 p. m.

San Joaquin Valley district.—Clear; heavy general firing began before 7 p. m. Lowest temperature in district 18°; average minimum all stations 24°.

Santa Paula district.—Clear except for a few clouds at intervals. Considerable wind over most of the district, with most stations registering minimum temperatures between 30° and 33°. Scattered moderate firing began about 10 p. m. Lowest temperature 25°.

Southern California.—Considerable broken cloudiness during the day, with rain squalls near the mountains. Considerable cloudiness during the early part of the night, varying in different districts: Moderate firing began between midnight and 2 a. m. in the Azusa, Pomona, Upland, and Redlands districts, and in the Los Angeles County portion of the Whittier-Orange County district. No firing in central and southern Orange County, and only light, scattered firing after 5 a. m. in the Corona district. Temperatures in the Imperial and Coachella Valleys remained above freezing all night. Lowest temperatures by districts: Whittier 25°; Azusa, Upland, and Corona 24°; Pomona 23°; Redlands 22°.

² Static electrical effects due to high wind velocity and extremely low humidity.

³ See "Notes on the 1922 Freeze in Southern California," MONTHLY WEATHER REVIEW November 1923, pp. 581-585.

January 3-9, 1937

Sacramento Valley district.—Clear; moderate to fresh northerly wind died out completely about 1:20 a. m., after which temperature fell rapidly from 27° to 15.5° at 5:30 a. m. Heavy firing after midnight.

San Joaquin Valley district.—Clear; heavy general firing began before 7 p. m. Lowest temperature in district 18°.

Santa Paula district.—Clear; wind over most of district held temperatures near or above 32° at most stations. Heavy firing began in sections sheltered from the wind about 7:30 p. m. Lowest temperature in district 21°.

Southern California.—Clear to partly cloudy during day; clear all night. Wind kept temperature above danger point in Orange County from Fullerton south to Anaheim, Orange, and Santa Ana, and caused strongly fluctuating temperature in all other sections. Heavy general firing began between 6 p. m. and 7 p. m. in the Pomona, Upland, Azusa, and Redlands districts, and in the Los Angeles County portion of the Whittier district, northern and extreme southern Orange County. Moderate general firing began in the Corona district about 10 p. m. Lowest temperatures by districts: Whittier, Azusa, Pomona, and Upland 22°; Corona 21°; Redlands 18°.

Imperial and Coachella Valleys.—Partly cloudy in early evening; clear thereafter. Lowest temperature in district 19°.

January 9-10, 1937

Sacramento Valley district.—Overcast sky all night. Snow began to fall about 4 a. m. and continued for about 42 hours. Amounts varied from 1 to 3 inches in vicinity of Oroville and Woodland to 15 to 18 inches in vicinity of Orland and Hamilton City. In the latter districts the fall was the heaviest ever recorded there. Lowest temperature in district 27°.

San Joaquin Valley district.—Clear; heavy general firing over entire district, beginning about 8 p. m. Lowest temperature 20°.

Santa Paula district.—Clear, scattered moderate to heavy firing in spots, beginning about 7:30 p. m. Wind held temperature above 32° at many points. Lowest temperature in district 20°.

Southern California.—Clear sky day and night. Wind held temperatures above the danger point in Placentia, Yorba Linda, Fullerton, and Anaheim sections, and caused widely fluctuating temperatures in most other districts. Moderate to heavy general firing in areas sheltered from the wind began about 5 p. m. in the Upland district, 6:30 p. m. in the Azusa, Pomona, and Redlands districts, 8 p. m. in the Whittier district, and 10 p. m. in the Corona district. Lowest temperatures by districts: Pomona, Azusa, and Whittier 23°; Upland 22°; Corona 21°; Redlands 19°.

Imperial and Coachella Valleys.—Clear; lowest temperature in district 21°.

January 10-11, 1937

Sacramento Valley district.—Overcast; snow continuing; lowest temperature 32°.

San Joaquin Valley district.—Lowest temperature 24°; no firing.

Santa Paula district.—Clear; light to heavy firing in a few small areas, beginning about 8 p. m. Temperature remained above 32° over most of district. Lowest temperature 22°.

Southern California.—Considerable cloudiness in the Whittier district and some intermittent cloudiness in other sections, during the early part of the night. Temperatures were much lower in the interior than near the coast. Light scattered firing began on low ground in the Azusa section about 8:30 p. m. Moderate scattered firing began in the Pomona and Upland districts about 7 p. m. Moderate general firing began in the Corona district about 8 p. m., in southern Orange County about 10:30 p. m., and in the remainder of the Whittier district about 2:30 a. m. Heavy general firing began in the Redlands district about 7 p. m. Lowest temperatures by districts: Whittier 26°; Pomona and Azusa 24°; Corona 23°; Upland 22°; Redlands 21°.

Imperial and Coachella Valleys.—Clear sky; lowest temperature 22°.

EFFECTS OF FREEZE OF JANUARY 7-11, 1937

Orchard heating in the Sacramento Valley was unusually difficult due to the strong winds which continued most of the time on the coldest nights. In one lemon orchard the fruit was abandoned after the first cold night, and heaters were lighted thereafter only for the protection of the trees. In the largest lemon orchard in the district, however, heavy firing carried most of the crop through the

* Practically no orchard heaters used in this district. Some protection obtained through running irrigation water in orchards and truck crop areas, and covering truck crops with brush, paper, tules, etc.

cold period without damage. Practically all lemon trees in the district were protected, and damage to orange trees was negligible. The last of the orange crop was hurriedly harvested before the freeze began.

In the San Joaquin Valley the freeze left all unheated lemons and Valencia oranges a complete loss as fresh fruit, but with a considerable portion thought to be of some value for byproduct manufacture. Navel oranges suffered slight to moderate damage in unprotected groves. Unprotected lemon trees suffered heavy defoliation, but damage to orange and grapefruit trees was confined to late fall growth as a general rule. There was no damage to fruit or trees in groves with standard heating equipment efficiently handled.

South of the Tehachapi Mountains all varieties of fruit were protected without difficulty in groves with adequate orchard heating equipment and fuel supply. Fuel for heaters designed to burn carbon briquets or petroleum coke became increasingly difficult to obtain as the freeze progressed, and by January 9 was almost unobtainable. Reserves at manufacturing plants had been entirely exhausted, and only the daily output of briquetting plants was available. More than 600 trucks and other vehicles waited in line for solid fuel as long as 48 hours. In desperation growers turned to wood, coal, discarded rubber tires, scrap rubber from manufacturing plants, peach and olive pits, and even hay and straw for orchard heating fuel. One large orchard burned nothing but baled alfalfa hay throughout one night, expensive but effective in saving tender lemon trees.

Orchard heater oil held out better than solid fuel, but by January 10 many growers received desperately needed oil supplies after nightfall and were forced to fill and light the heaters simultaneously. A few growers lost their crops on this night because of inability to secure fuel.

The second and more severe freeze of the winter arrived before the amount of damage caused by the first freeze could be determined accurately. Estimates placed the damage at 15 percent to Navel oranges and lemons and 18 percent to Valencia oranges and grapefruit. With the exception of lettuce, vegetable crops in the Imperial and Coachella Valleys suffered heavy damage. Although this freeze caused extensive damage to avocado trees and tropical plants, damage to citrus trees south of the Tehachapi Mountains was almost negligible.

SECOND FREEZE OF JANUARY 1937

A period of cool cloudy weather, with frequent rains, followed the termination of the first January freeze. Fruit growers had hardly recovered from their exhaustion following the battle to save the crop when on the morning of January 18 it became apparent that a second freeze was imminent. A barometric depression moved rapidly southward from northwestern Canada, increasing in intensity, followed by another influx of polar air. On that date all packing-house managers were warned of the approach of another severe freeze which would necessitate several nights of heavy general firing of orchard heaters. Refilling of oil storage tanks, emptied during the first freeze, had been discouragingly slow, due largely to a feeling on the part of the growers that two severe freezes could not occur during the same winter. No basis for such a belief existed, since two severe freezes had arrived about a week apart in January-February 1922. In a few cases it was necessary to use the strongest possible measures to convince local cooperative association managers who were negotiating for lower oil prices, of the seriousness of the situation.

No such difficulty was experienced in dealing with central cooperative purchasing organizations, oil companies, or the railroads. Every agency for the expedition of orchard heater fuel transport was instantly mobilized and all possible preparations were made for the second battle with the cold. Special railroad switching crews were placed in railroad yards near oil refineries to expedite movement of tank cars, special crews for loading cars were gathered, and every motor truck equipped for fuel transportation was placed in service.

The first effects of the new freeze were felt on the night of January 19-20 simultaneously throughout the length of the California citrus belt, but there was considerable intermittent cloudiness during the night in all sections but the Sacramento Valley, and temperatures in general outside that section did not fall very low. On the morning of the 20th a warning was given the widest possible distribution that the freeze would bring the lowest temperatures in 24 years to southern California, and efforts to prevent failure of fuel supplies were redoubled. Generally speaking, the night of January 20-21 was the coldest in northern and central California districts, while the following night was coldest in southern districts. Day-by-day notes on the freeze by districts are given below.

January 19-20, 1937

Sacramento Valley District.—Clear; moderate to fresh north wind, decreasing in velocity at times after midnight. Heavy firing for lemons began about 11 p. m., and continued until 9:30 a. m. Despite protective efforts all lemons brought through the first freeze undamaged were badly frozen. Lowest temperature, 18°.

San Joaquin Valley District.—Considerable cloudiness during the first part of the night. Scattered light firing began about midnight. Lowest temperature, 25°.

Santa Paula District.—Some cloudiness at intervals, and intermittent wind in spots during the night. Quite general light to heavy firing over the district, although temperatures remained above the danger point in some localities. Lowest temperature, 22°.

Southern California.—Some cloudiness at intervals in all sections during the night, heaviest in Orange County. Moderate to heavy general firing began about 7 p. m. in Pomona and Upland districts, about 8 p. m. in Corona and Redlands, and 9 p. m. in Azusa. Moderate firing began in the Whittier district about 10:30 p. m. north of Orange. No heaters were lighted south of Orange. Lowest temperatures by districts: Whittier, Azusa, and Pomona, 24°; Corona and Upland, 22°; Redlands, 21°.

Imperial and Coachella Valleys.—Wind and clouds maintained safe temperatures over practically the entire district. Lowest temperature, 26°.

January 20-21, 1937

Sacramento Valley District.—Clear; moderate to fresh north wind practically all night in Maxwell lemon-growing district maintained temperatures above the danger point for trees, and since all fruit had been frozen, heaters were not lighted. Some firing after midnight for orange trees near Hamilton City. Lowest temperature in district, 15°.

San Joaquin Valley District.—Clear. General heavy firing began before 7 p. m. All unprotected fruit in district which might have escaped damage in first January freeze destroyed on this night. Fruit damage in lemon and orange groves equipped with orchard heaters varied from zero to heavy, depending on equipment, efficiency of firing, and location. Complete defoliation of practically all unprotected lemon trees; some defoliation in many heated lemon groves. Unprotected orange and grapefruit trees 50 percent defoliated in small areas, chiefly in southern portion of district; large areas showed no defoliation. Heaviest defoliation in areas with highest average winter minimum temperature. Lowest temperature in district, 14°, the lowest official temperature recorded since establishment of Fruit-Frost Service in November 1922.

Santa Paula District.—Some cloudiness and considerable wind in open sections during night. Light to heavy general firing began about 7 p. m., although minimum temperatures over most of the district ranged from 28° to 31°. Lowest temperature in district, 21°.

Southern California.—Considerable cloudiness up to midnight in all areas, continuing in some sections until nearly morning. Wind prevented temperature fall in some sections until 4 a. m., after which there was a sudden drop, which caught many growers napping and resulted in some damage in fired groves. Light scattered firing

began in Pomona, Upland, and in the western portion of the Whittier district from 8 p. m. to 8:30 p. m., becoming heavy between 4 a. m. and 6 a. m. Moderate general firing began in the Corona district about 1 a. m. and in the Azusa district at 4:30 a. m. Heavy general firing began in the Redlands district about 2 a. m. No firing in Whittier district south of Orange. Lowest temperatures by districts: Whittier, 22°; Upland, Pomona, Azusa, and Corona, 21°; Redlands, 16°.

Imperial and Coachella Valleys.—Wind and clouds at intervals. Lowest temperature, 25°.

January 21-22, 1937

Sacramento Valley District.—Clear until arrival of some alto-cumulus clouds about 2:30 a. m. Very little wind; temperature fell to 21° by 10:30 p. m. Firing for lemon trees began about 11:30 p. m. Lowest temperature, 18°.

San Joaquin Valley District.—Clear; general heavy firing began before 7 p. m. Lowest temperature, 17°.

Santa Paula District.—Clear sky; less wind than previous night, but sufficient in a few open areas to hold temperature up to 30° to 32°. Light to heavy general firing, depending on location, began about 8 p. m. and continued until 10 a. m. Lowest temperature in district, 18°.

Southern California.—Clear; considerable wind in some areas before midnight, but little thereafter. Temperature dropped 11° in a half hour in southern Orange County when wind lulled. Moderate to heavy general firing began 4 p. m. to 6:30 p. m. in Upland, Redlands, Pomona, Azusa, and northern portion of Whittier district; 9:30 p. m. in Fullerton-Placentia section; 11 p. m. in Corona and southern portion of Whittier district. Lowest temperatures by districts: Azusa, 21°; Pomona, 20°; Upland and Whittier, 19°; Corona and Redlands, 16°.

Imperial and Coachella Valleys.—Clear; north wind died out in early evening. Lowest temperature, 12°.

January 22-23, 1937

Sacramento Valley District.—Clear; northerly wind during most of the night, with rapid temperature fall during lulls. Light firing for tree protection only began about 4 a. m. Lowest temperature, 20°.

San Joaquin Valley District.—Clear except for a few high clouds at long intervals. General heavy firing began about 7:30 p. m. Lowest temperature, 16°.

Santa Paula District.—Considerable cloudiness during early part of night. Although firing probably was more general throughout the district on this night than any other during the freeze, minimum temperatures ranged from 29° to 36° at many points due to wind. Light to heavy firing, depending on location, was fairly general after about 10 p. m. Lowest temperature in district, 22°.

Southern California.—Overcast sky all day. Clouds began to break between 8:30 p. m. and 10:30 p. m., and sky was clear in all sections by 11 p. m. Considerable wind in some sections, notably in parts of Orange County. Lowest temperatures were well above the danger point in the vicinity of Anaheim, Olive, and Yorba Linda. Moderate to heavy general firing began about 6 p. m. in Upland and Pomona districts; 7 p. m. in Azusa; 8 p. m. in Redlands and northern portion of Whittier district; and 11:30 p. m. in Corona and the southern portion of the Whittier district. In several sections the temperature dropped below the danger point while the sky was still overcast with low clouds. Lowest temperatures by districts: Whittier, 22°; Upland, Pomona, and Azusa, 20°; Corona, 18°; Redlands, 15°.

Imperial and Coachella Valleys.—Cloudy first part of night; clear during latter part. Little wind. Lowest temperature, 12°.

January 23-24, 1937

Sacramento Valley District.—Cloudy during most of the night. No firing. Lowest temperature in district, 26°.

San Joaquin Valley District.—Clear sky until toward morning. General heavy firing began about 7 p. m. Lowest temperature in district, 22°.

Santa Paula District.—Clear sky except for a few clouds at long intervals. Considerable wind in some areas, holding temperature at 32° in spots. Moderate to heavy general firing, except in windy areas, began about 7:30 p. m. Lowest temperature, 22°.

Southern California.—Clear all night in inland districts, but considerable cloudiness in districts nearest the ocean before morning. Cloudiness began in the Whittier district about 2:30 a. m., and in the Azusa district about 6 a. m. Considerable wind in all open sections, causing extremely spotted temperature conditions. Firing was light to moderate, scattered in the Azusa and Whittier districts, beginning between 7 p. m. and 8:30 p. m.; and heavy general, beginning between 5 p. m. and 5:30 p. m. in Redlands, Upland, and

Pomona, and 6:30 p. m. in the Corona district. Lowest temperatures by districts: Whittier, 24°; Azusa, 23°; Upland and Pomona, 22°; Corona, 20°; Redlands, 16°.

Imperial and Coachella Valleys.—Clear; little wind; lowest temperature, 17°.

January 24-25, 1937

Sacramento Valley District.—Clear; some wind in spots. Light firing for lemon tree protection only began about 4 a. m. Lowest temperature in district, 21°.

San Joaquin Valley District.—Clear sky except for a few scattered high clouds. Light scattered firing began late in the night. Lowest temperature, 22°.

Santa Paula District.—Intermittent cloudiness during much of the night, varying in different sections. Considerable wind in some sections. Minimum temperatures well above 32° at many points. Light scattered firing 3 to 4 hours before sunrise. Lowest temperature, 26°.

Southern California.—Intermittent broken cloudiness during most of the night, heaviest in the Whittier district. Little wind. Light

No firing in Whittier district. Light scattered firing began in Azusa about 11 p. m. Moderate general firing in Corona district about 9 p. m. Heavy general firing began about 9 p. m. in Upland and Pomona, and 10 p. m. in Redlands. Lowest temperatures by districts: Whittier, 26°; Azusa, 25°; Pomona, 24°; Corona and Upland, 23°; Redlands, 20°.

Imperial and Coachella Valleys.—Clear; little wind. Lowest temperature, 16°.

January 26-27, 1937

By this date a low-pressure area in the Pacific Northwest had spread sufficiently far southward to cause southwest winds over practically all of California. Damagingly low temperatures continued in the Imperial and Coachella Valleys, with the minimum for the district 20°, but lowest temperatures in other districts ranged from 26° to 29°. There was light scattered firing in the Santa Paula, Azusa, Pomona, and Redlands districts, beginning between 10 p. m. and midnight, but heaters were extinguished later in the night in most localities when the sky clouded over. Heaters were not lighted in any other district.

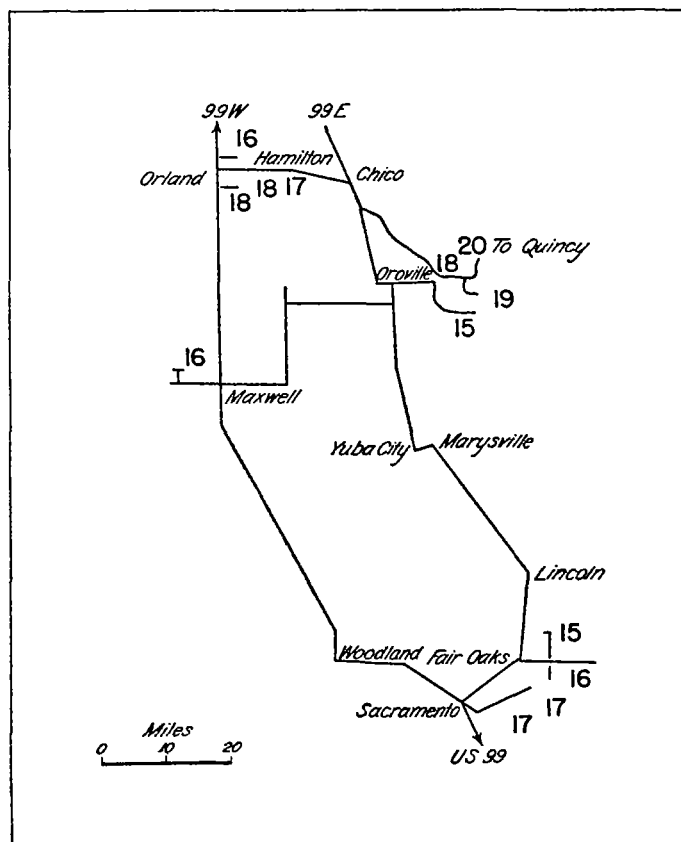


FIGURE 1.—Lowest temperature recorded in citrus groves during 1936-37 season in Sacramento Valley.

scattered firing on low ground in the Azusa district about 9 p. m. and in the northern portion of the Whittier district about 1 a. m. Moderate general firing began in Upland about 6:30 p. m., Corona, Redlands, and Pomona about 9 p. m. No firing in the southern portion of the Whittier district or on high ground in the Azusa district. Lowest temperatures by districts: Whittier, 27°; Pomona and Azusa, 25°; Corona and Upland, 24°; Redlands, 23°.

Imperial and Coachella Valleys.—Clear; little wind; lowest temperature, 20°.

January 25-26, 1937

Sacramento Valley District.—Considerable cloudiness in western portion of the district, with lowest temperatures above 32° at many points. Light firing for lemon tree protection. Lowest temperature in district, 23°.

San Joaquin Valley District.—Some scattered cloudiness during the latter part of the night. Light scattered firing began late in the night. Lowest temperature in district, 24°.

Santa Paula District.—Clear; wind in open sections. Lowest temperatures at many points above 32°. Scattered light to heavy firing began about 1 a. m. Lowest temperature, 22°.

Southern California.—Clear; little wind in most sections, although temperatures at a few individual stations did not drop below 32°.

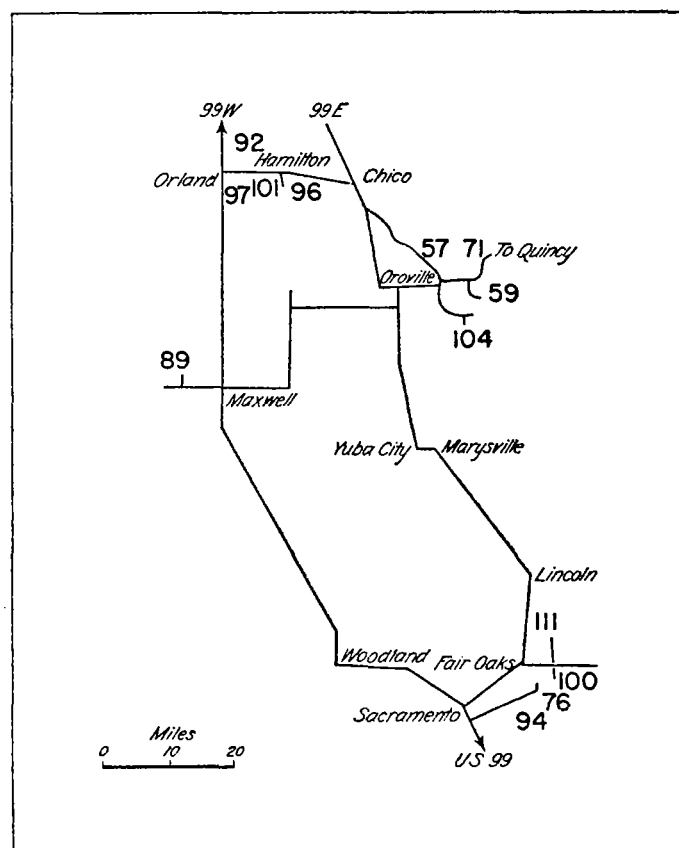


FIGURE 2.—Total number of hours the temperature was 27° or lower in the citrus groves of Sacramento Valley during the 1936-37 season.

January 27-28, 1937

This night marked the end of the freeze. The only temperature below the danger point was 24° in the Imperial Valley. Lowest temperatures in other districts ranged from 27° to 37°. There was no firing in any district.

COMPARISON BETWEEN 1913, 1922, AND 1937 FREEZES

Temperatures recorded in southern and central California citrus districts in January 1937 were the lowest since January 1913. In the Sacramento Valley lower temperatures were registered during the record breaking freeze of December 1932. While data are available from only a few points, it is possible to make fairly direct comparisons between minimum temperatures recorded during the January freezes of 1913, 1922, and 1937.

TABLE 1.—Minimum temperature for district (°F.)

Station	January 1913	January 1922	January 1937
Redlands	18	19	17
Riverside	21	19	20
Indio	16	23	13
Calexico	21	23	14
San Bernardino	18	22	17
Fontana		24	16
Claremont	19	20	22
Pomona	18	18	20
Sierra Madre	28		23
Yorba Linda	26	26	24
Tustin	32	23	22
Porter Jile	18	22	19
Lindsay	13	20	18
Lemon Cove	18	21	18

† Minimum temperature readings affected by orchard heating in vicinity.

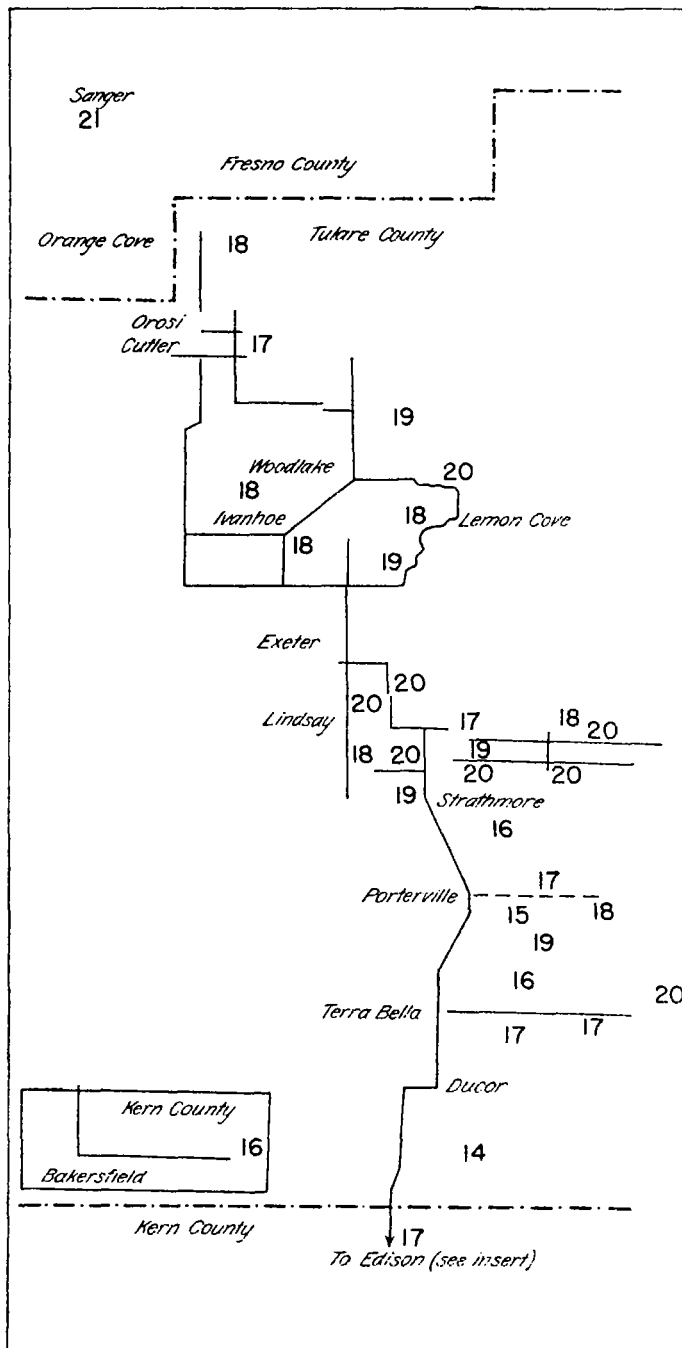


FIGURE 3.—Lowest temperatures recorded in citrus groves during the 1936-37 season in central California.

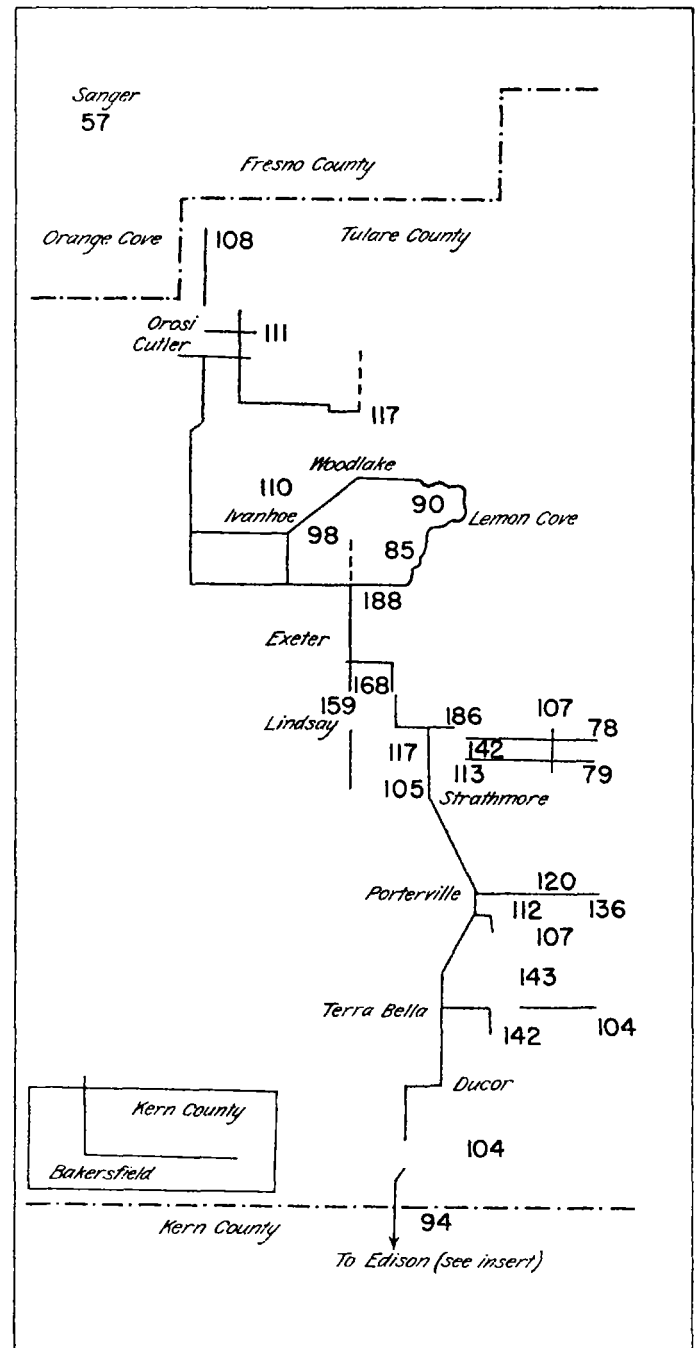


FIGURE 4.—Total number of hours the temperature was 27° or lower in citrus groves during the 1936-37 season in central California.

While some of the temperature data in table 1 are not strictly comparable because of slight changes in the location of thermometers since 1913, they are the best that are available. Temperatures at Redlands, Riverside, Pomona, and Claremont were influenced in 1937 by mass orchard heating in the vicinity of the stations. The amount of this effect on the minimum temperature is very difficult to estimate, but probably was 1° or 2° at Redlands, 4° at Riverside and Claremont, and 5° at Pomona. At all points listed in the table located in districts where there was little or no orchard heating in 1937 minima are lower than those of 1922, in some sections very much lower.

The records indicate that minimum temperatures in San Joaquin Valley citrus districts were about the same

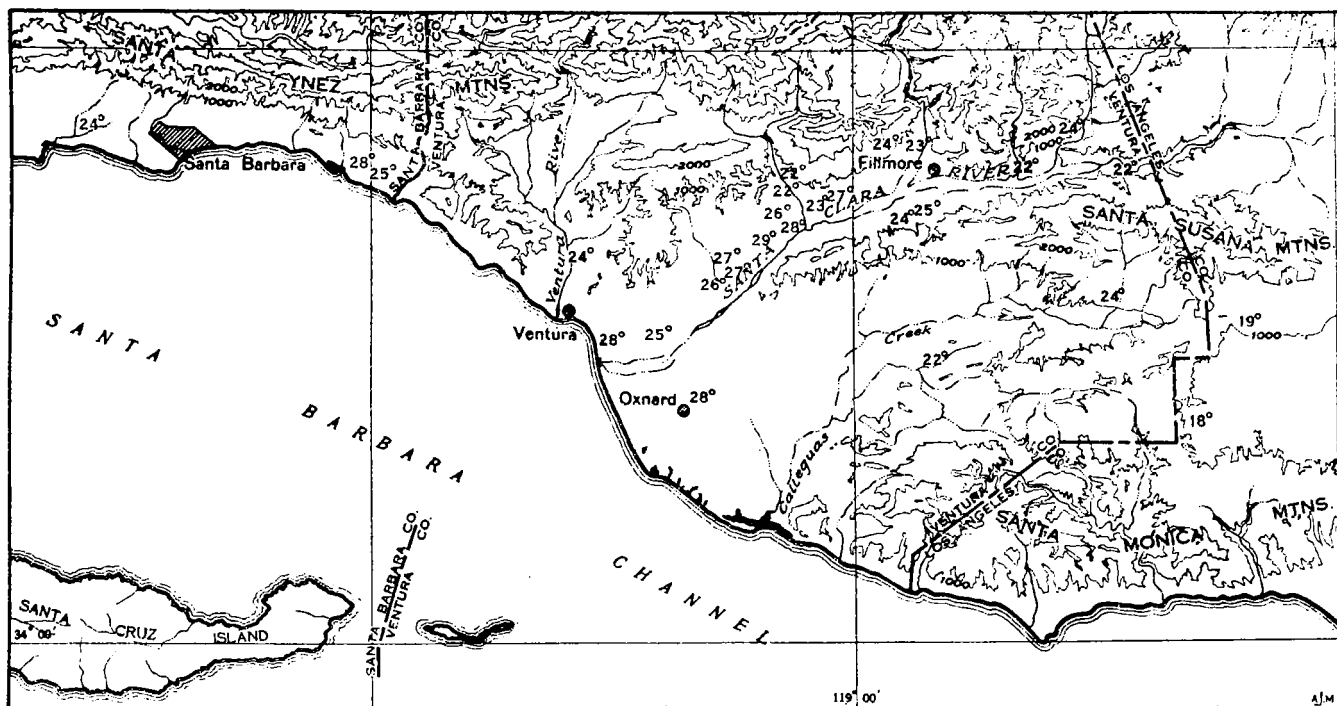


FIGURE 5.—Lowest temperatures recorded in citrus groves during the 1936-37 season in Ventura and Santa Barbara Counties.

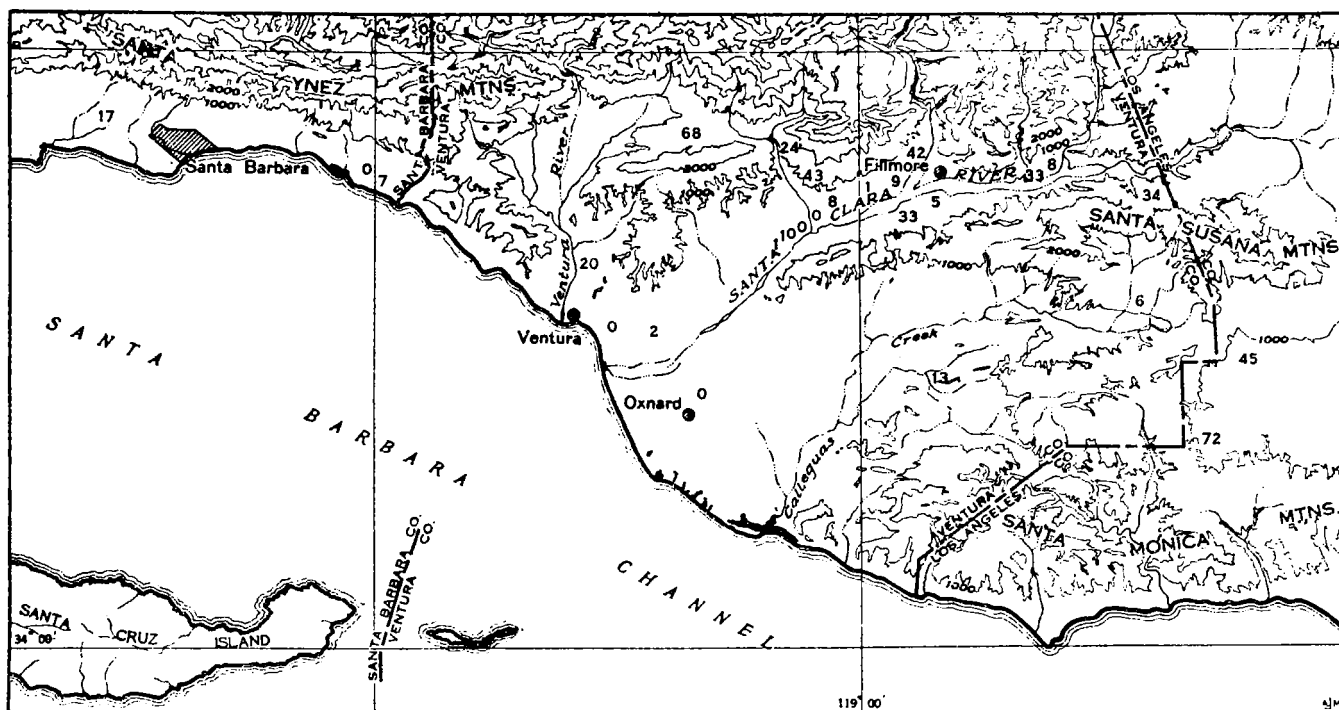


FIGURE 6.—Total number of hours temperature was 27° or lower in citrus groves during the 1936-37 season in Ventura and Santa Barbara Counties.

or slightly lower in 1913 than in 1937. In southern California, however, all the evidence indicates that the temperature fell as low or lower in 1937 than in 1913.

Duration of the 1937 freeze was definitely longer than either the 1913 or 1922 freeze, both in central and southern California. In the San Joaquin Valley the 1913 freeze continued 4 days, January 5 to 8, inclusive. In southern California it continued from 1 to 4 days, depending on locality. The 1922 freeze continued for 6 days in central California, and from 4 to 6 days in southern California. During the two freezes of January 1937

there were 10 days with temperatures below the danger point in central California and 11 days in southern California. Considering both temperature and duration, the 1937 freezes broke all known records in all California citrus districts except those in the Sacramento Valley.

Intensity of the freeze naturally varied considerably in different localities. Figures 1 to 10 show lowest temperatures registered during the winter of 1936-37, together with total number of hours the temperature was 27° or lower during the season, for all citrus districts in which the Weather Bureau Fruit-Frost Service operates.

The influx of polar air into California, particularly southern California, took place much more rapidly in 1937 than in 1922, and was much longer sustained. During the second freeze the stream of frigid air was very deep, which had much to do with the unusual length of the cold period. On the evening of January 19 the wind at 12,000 feet was north-northwest 76 miles per hour at San Diego and north-northeast 75 miles per hour at Seattle. On the following night the wind at the same elevation was north-northeast 66 miles at Medford and north 52 miles at San Francisco. Even as late as the evening of the 24th winds at 12,000 feet were from 44 to 48 miles per hour from the north in western Oregon and northern California.

One of the most interesting features connected with the 1937 freezes was the slight temperature inversion near the ground and the fact that in some districts orchards at the highest levels in the foothills were above the top of the inversion. Many orchards on the higher slopes, where the temperature had not dropped even to 32° for many years due to excellent air drainage, experienced temperatures far below the danger point not only for fruit but for trees. As a matter of fact orchards at highest elevations on the north slope of the Great Valley of southern California registered the lowest temperatures and suffered the heaviest tree damage in the southern part of the State. This was due not only to lack of inversion above the groves, but also to increased wind movement, the fact that there was no orchard heating to windward, and the greater susceptibility to damage of the trees resulting from lack of frosts earlier in the season. A comparison between 1922 and 1937 temperature inver-

sion data for the same two stations located on an isolated ridge near Pomona, with a difference of 225 feet in elevation, shows a minimum inversion of 9° F. in 1922 and 2.2° F. in 1937.

The following table showing inversion data in 1937 is of interest. Heavy general orchard heating on the valley floor undoubtedly interfered with normal inversion development despite the fact that all stations listed in the table were located in groves not equipped with orchard heaters.

TABLE 2.—Minimum temperatures at elevations from near valley floor to foothills

UPLAND DISTRICT				
Date (1937)	Station 45 1,025 ft. m. s. l.	Station 18 1,625 ft. m. s. l.	Station 48 1,850 ft. m. s. l.	Station 17 2,150 ft. m. s. l.
January 9.....	22.3	24.9	23.0	22.0
January 20.....	23.2	28.0	27.1	24.0
January 21.....	22.0	24.6	23.0	21.0
January 22.....	21.5	24.4	24.0	21.9
January 23.....	22.7	25.3	23.4	22.0
January 24.....	23.9	27.9	27.0	25.2
January 25.....	24.0	29.1	32.4	29.0
REDLANDS DISTRICT				
Date (1937)	Station 63 1,625 ft. m. s. l.	Station 47 1,710 ft. m. s. l.	Station 39 1,875 ft. m. s. l.	Station 64 2,250 ft. m. s. l.
January 9.....	22.8	21.1	18.9	18.0
January 20.....	26.1	25.0	24.2	23.0
January 21.....	21.6	20.0	17.8	16.0
January 22.....	21.6	17.2	18.0	16.0
January 23.....	24.8	17.8	18.0	15.0
January 24.....	23.8	22.0	24.0	21.0
January 25.....	26.5	25.4	27.0	25.0

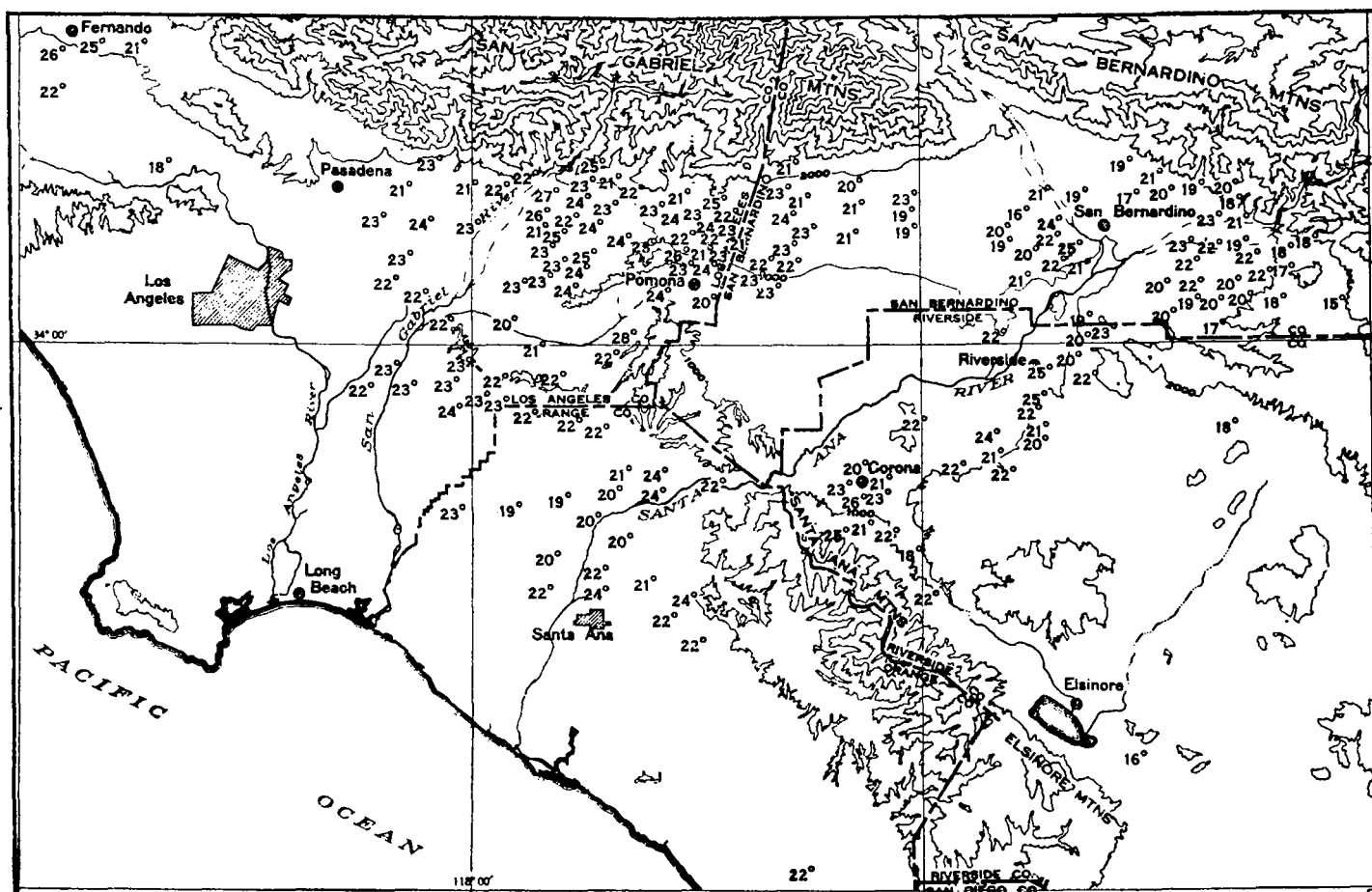


FIGURE 7.—Lowest temperatures recorded in citrus groves during the 1936-37 season in southern California.

Minimum temperatures for the freeze period at higher elevations in the mountains were: Mt. Wilson, elevation 5,850 feet, 7° F.; Squirrel Inn, elevation 5,700 feet, 0° F.; and Seven Oaks, elevation 5,000 feet, 0° F.

FORECASTS

The value of weather forecasts of any kind depends to a great extent on the timeliness with which they reach the people for whom they are intended. An elaborate telephone frost warning system in use in 1922 broke down completely during the freeze of that year. Each grower reached with a warning immediately called his firing crew, his neighbors, his cooperative association manager, and

State within a few minutes after the forecast had been completed, adequate dissemination of the forecasts would have been impossible. In addition to nightly broadcasts at 8 p. m., giving every possible item of information which might assist the growers in their battle to save the crops, a brief statement was made at 1:55 p. m. daily throughout the freeze periods.

Conditions expected during the night, including cloudiness, wind, rate and character of temperature fall, deposit of ice on trees and fruit, temperature inversion, and time necessary to begin firing, together with a forecast for the following night, were given for 10 different fruit growing districts in the night broadcasts. Definite minimum temperature forecasts for 76 different temperature

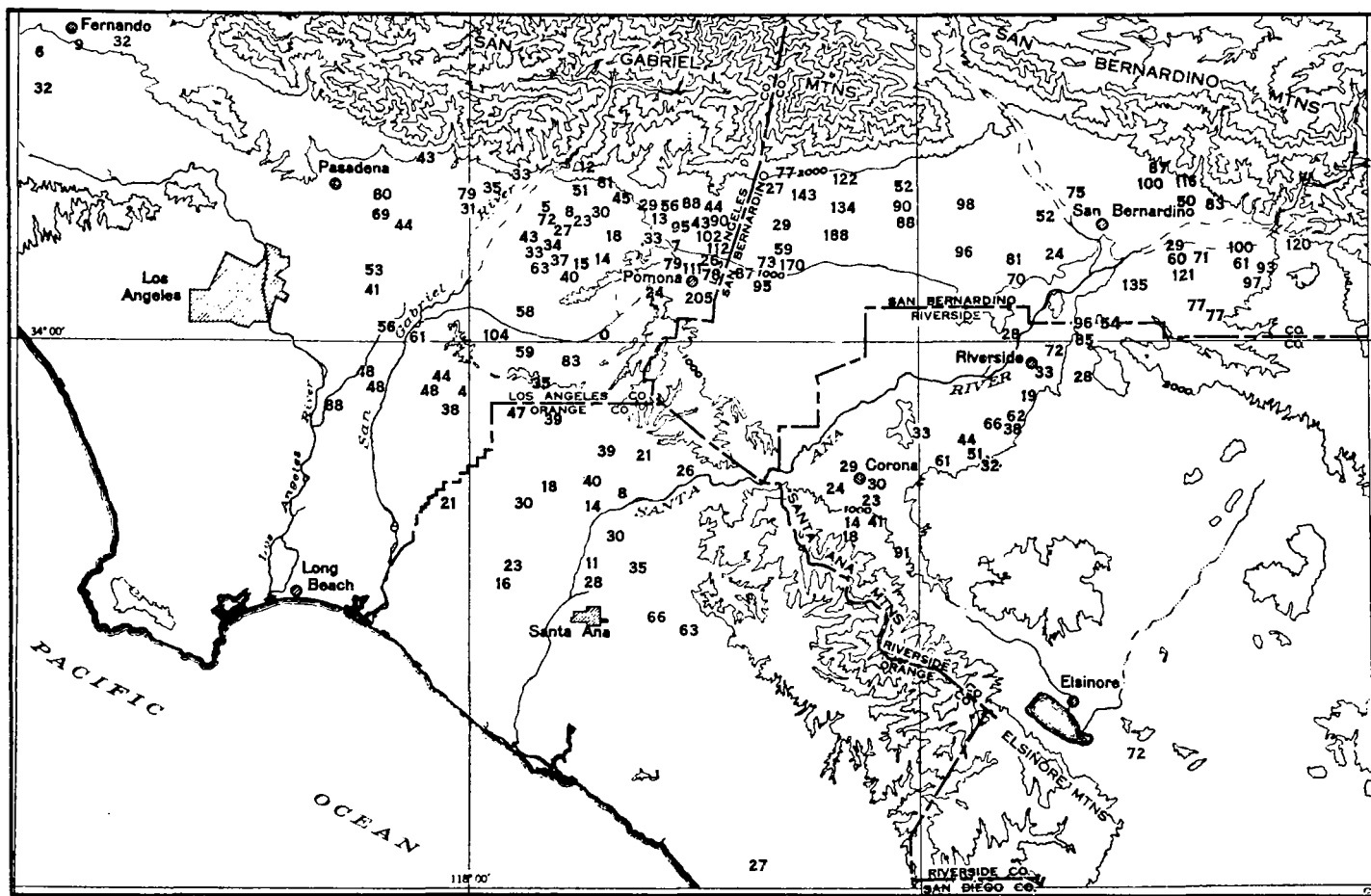


FIGURE 8.—Total number of hours temperature was 27° or lower in citrus groves during the 1936-37 season in southern California.

the Weather Bureau Office, causing a complete tieup of both local and long distance telephone lines. Much of the loss of fruit and trees suffered at that time might have been avoided had all growers been able to obtain the warning promptly.

Since 1930 minimum temperature forecasts have been broadcast nightly during the frost season over a powerful Los Angeles radio station direct from the Weather Bureau Office at Pomona over remote control lines. Continuation of this arrangement by the Columbia Broadcasting Company after its purchase of the station in 1936 was accomplished in the face of great difficulties, due to chain program releases. Without this public spirited cooperation, making it possible to reach every citrus grower in the

stations in the citrus districts followed. Temperature forecasts also were given to subscribers on request by central telephone operators in some localities, and were thrown on screens or announced over sound equipment in motion picture theaters.

Increasing difficulty in obtaining orchard heater fuel and inability to maintain what they considered to be safe temperatures through orchard heating caused many growers to become discouraged during the second freeze and consider abandoning the fight. With this situation in mind the following broadcast to growers in southern California was made at 1:55 p. m. on January 21.

With the eastward passage of the southwestern low-pressure area a great mass of frigid air from interior western Canada has moved

southward and settled over the Plateau Region and the Southwest. Temperatures this morning were below zero over practically all of the interior northwestern quarter of the country, and in northern Nevada the temperature at 5 a. m. was 30° below zero, breaking the all-time record for that section.

Conditions this morning are very similar to those which prevailed during the 1922 freeze, but it is expected that the temperature will

fall 2° or 3° lower in the coldest spots than it did in 1922. The lowest temperatures will be recorded in sheltered spots on the low ground, and it is expected that they will be as low as 16° by morning. Temperatures in areas unsheltered from northeast winds will be somewhat higher, but even in windy sections the temperature will drop to 24° or 25°. Firing will begin in some locations by 5:30 p. m. and will continue until at least 10 a. m. tomorrow. Growers

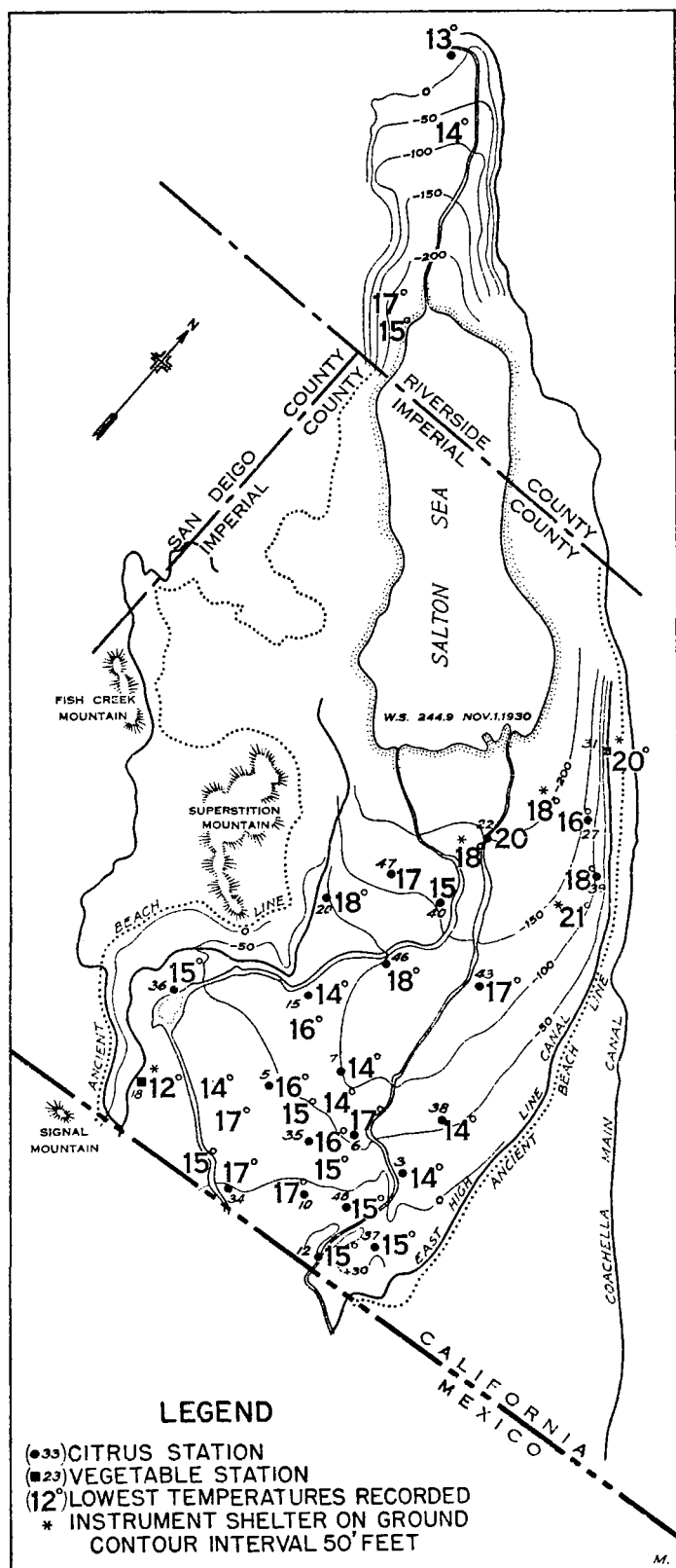


FIGURE 9.—Lowest temperatures recorded in citrus groves and winter truck crop areas in Imperial and Coachella Valleys.

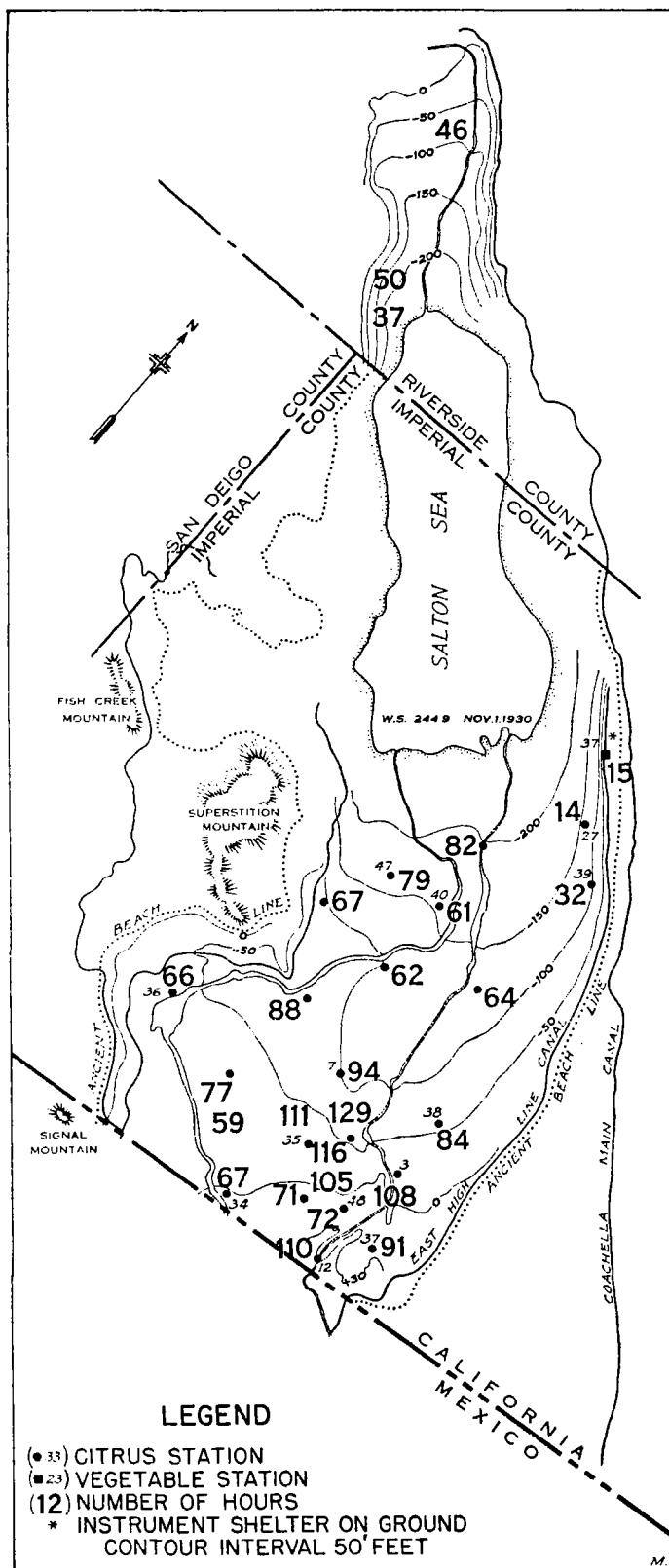


FIGURE 10.—Total number of hours temperature was 27° or lower in citrus groves and winter truck crop areas during the 1936-37 season in Imperial and Coachella Valleys.



FIGURE 11.—Contrast between protected and unprotected mature lemon trees following 1937 freeze. Even tender buds and blossoms in protected groves were undamaged.

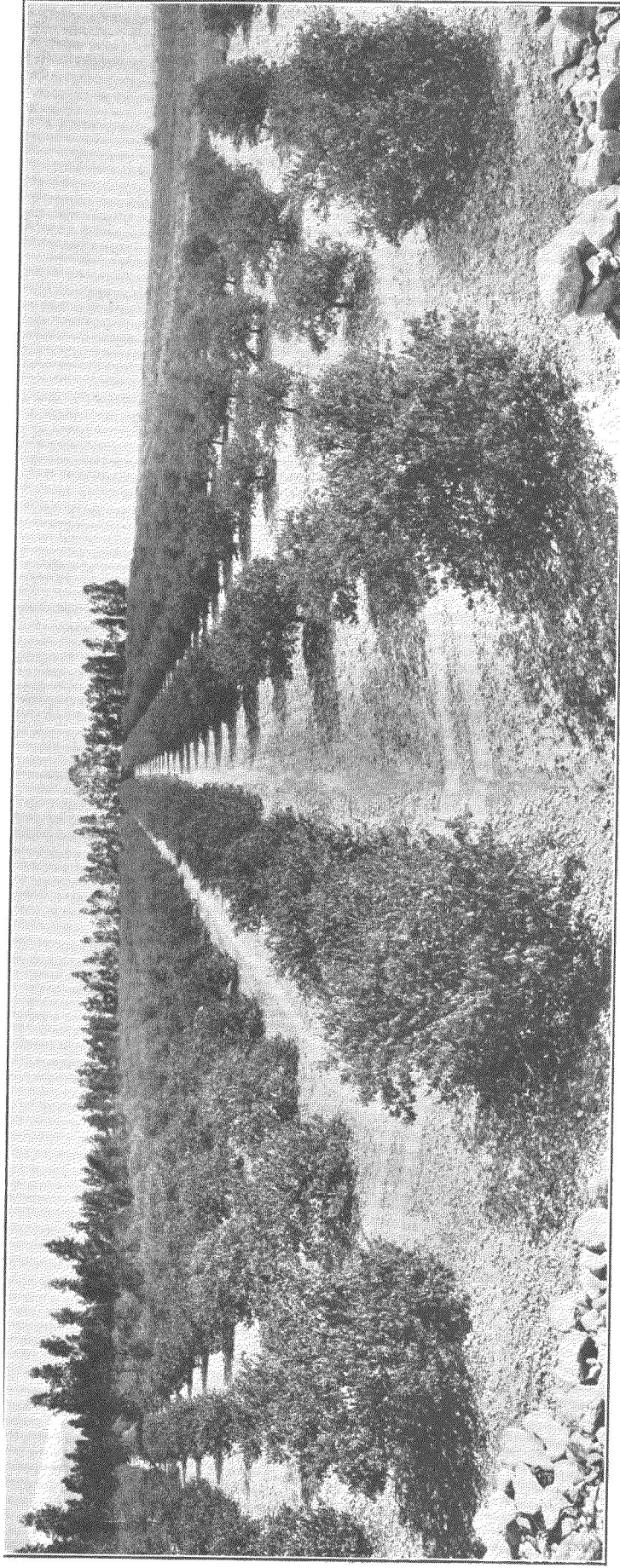


FIGURE 12.—View of mature lemon grove without protection; every tree killed to the ground.

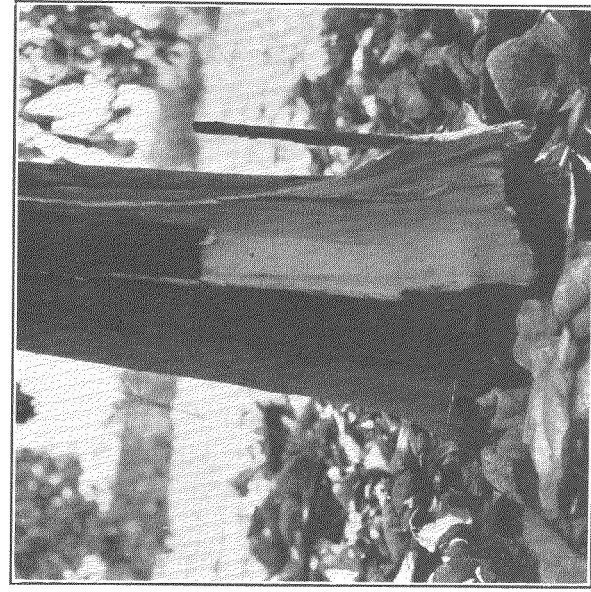


FIGURE 13.—25-year-old lemon tree with bark split by low temperatures; no protection.

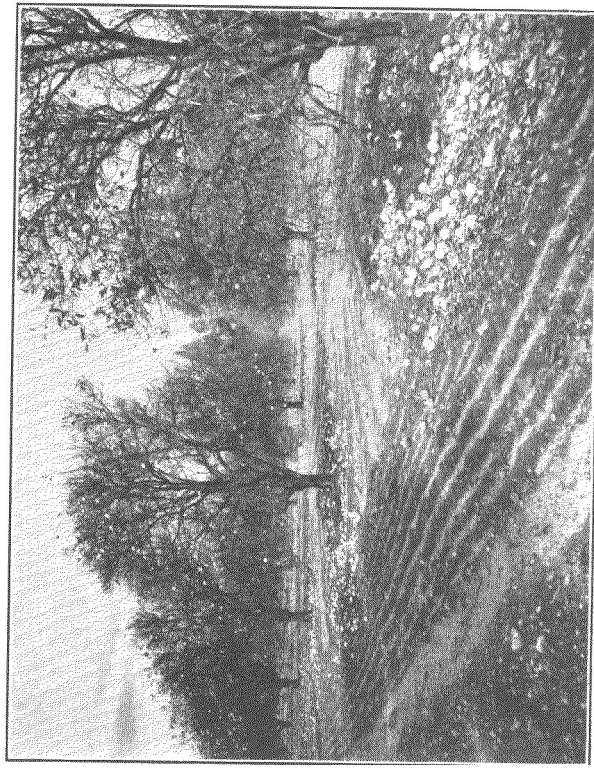


FIGURE 14.—Mature grapefruit trees, unprotected, showing complete loss of crop and defoliation.

who have tank wagons should have them filled and ready for action so that heaters can be refilled during the night where necessary.

Experience during the 1913 and 1922 freezes was that considerable fruit was salvaged in groves in which the heaters were kept burning all night, even when the temperature could not be maintained above the danger point. However, in cases where the grower plans to make no further effort to save the crop, the probability of severe tree damage should be kept in mind.

✓ Mature lemon tree foliage damage usually starts at long continued temperatures of 26°, and 24° for a long period will cause about 50 percent defoliation. Twenty-three degrees will cause complete defoliation and bark will be split by long continued temperatures of 19°.

✓ Severe foliage damage to mature orange trees is likely to follow long continued temperatures of 23°, and almost complete defoliation and some bark splitting on branches has resulted from temperatures of 18°.

✓ Young trees are, of course, much more susceptible to damage, and the temperature should not be allowed to fall below 26° in young groves if all damage is to be prevented.

After the sun is high enough in the morning, heaters can be extinguished even though the thermometer still reads slightly below the danger point.

Lowest temperatures tomorrow night will be only slightly higher than tonight, and present indications are that this freeze will have to wear itself out slowly, with probably some improvement each day, but with firing for three more nights.

Advice to continue the battle and keep the heaters burning as long as it was humanly possible to do so was repeated in the evening broadcast. Its soundness was demonstrated in hundreds of cases of little or no damage to fruit or trees in groves heated consistently despite temperatures which appeared to be considerably below the danger point.

The load on the telephone lines was extremely heavy during the freeze despite the dissemination of the forecasts by radio. Requests for elimination of social telephone calls so that lines could be kept clear for frost protection business were broadcast by telephone company officials. Telephone exchanges in citrus districts carried loads from 80 percent to 90 percent above normal throughout the freeze periods. On January 21 all records for traffic volume were broken at Pomona, with 94,000 calls, and at Covina with 49,900 calls. The manager of the Associated Telephone Company reports:

A noticeable falling off of telephone traffic occurs just previous to the evening broadcast. On cold nights this is immediately followed by a rush of calls as ranchers call for assistance, business men call for clerks to cover merchandise, and housewives call neighbors and friends to prepare to protect furnishings, etc. Socials, business meetings, even church services, are quite generally stopped to listen to the broadcast during critical periods.

At Pomona three telephones were kept busy constantly throughout the period of the two freezes, and telephones at nine other fruit-frost district headquarters in the field were similarly busy. The extreme nervous tension under which growers and their families were laboring was reflected in their voices. In many cases women burst into tears after obtaining the forecast by telephone.

The Board of Directors of the California Fruit Growers Exchange in a resolution commending the forecasting work stated in part:

The interpretation of weather data * * * resulted, as usual, in forecasts so accurate that not only could crops be saved through heating, but by proper timing considerable fuel oil could be saved for the next emergency, which was vital during such long periods of low temperature, both from the standpoint of costs and conservation of fuel supply.

The Mutual Orange Distributors, another cooperative citrus marketing agency, published the following in its grower magazine:

It is beyond doubt that the work of the frost protection and notification program of the United States Weather Bureau at Pomona was highly efficient. Had all of the factors in frost protection been as well organized as this, the loss undoubtedly would have been much

less. Regular evening broadcasts over KNX were supplemented by bulletins to sales organizations and other central parties at frequent intervals throughout the day. The general accuracy of all forecasts was remarkable.

The following is quoted from a letter from the Los Angeles Chamber of Commerce:

Value of the broadcasts was doubly manifested because of the extreme irregularity of the temperature. Certain localities that had previously been thought to be exempt from frost damage experienced subnormal temperatures, ample warning of which was given, thereby making it possible to be prepared.

From the Whittier State School:

It was through the warning of the approaching frigid wave that this institution purchased its first heating units for the citrus grove, and, of course, we were successful in saving not only practically all of the fruit, but we eliminated tree damage as well.

DAMAGE CAUSED BY FREEZES

The amount of damage to citrus crops by low temperature is very difficult to estimate. Any loss estimate in percentage of the total crop must be based on an estimate of the size of the crop on the trees before the damage took place. At the end of the season the California Fruit Growers Exchange estimated the amount of fruit rendered unfit for shipment through freezing injury at 40 percent of the crop on the trees when the freeze began. Approximately one-third of the State Navel orange crop had been picked before the first freeze began. Ninety percent of the Navel crop in the San Joaquin Valley had been harvested. As nearly as can be estimated, citrus fruit rendered unfit for shipment by the freezes represented approximately 30 percent of the total crop on the trees at the beginning of the season. This compares with 62 percent damage by the 1913 freeze and 50 percent by the 1922 freeze.

The 1937 loss of citrus fruit through freezing damage was 16,000,000 boxes, or 35,000 carloads. In addition to the fruit rendered valueless except for byproducts, it is estimated that approximately 10,000 carloads of fruit was damaged slightly, necessitating its marketing in lower grades which sold at a lower price than undamaged fruit.

It is even more difficult to estimate the value of the fruit damaged by low temperatures, since the price per box was considerably higher than it would have been if the entire crop on the trees before the freeze had been shipped. Actually the 1937 crop brought to California approximately \$9,000,000 less than the crop of the previous season. The 1937 crop, 30 percent less in volume than the 1936 crop, brought only 8 percent less return. In other words, the California crop alone cost consumers nearly \$25,000,000 more because of the freeze, based on the per box consumer cost of the 1936 crop. Prices for the Florida crop were increased proportionately, making the total cost of the freeze to the consumer probably in excess of \$50,000,000. If there had been no frost protection in California the 1937 crop would have been reduced in size much more drastically, and prices to the consumer would have been much higher.

If the \$9,000,000 loss to the California growers due to the freeze had been evenly distributed, the results would not have been very serious. As a matter of fact, however, many growers without frost protection equipment, as well as a few who spent large amounts for frost protection but who were unable to secure sufficient fuel to carry through the entire freeze, lost their entire crops, while others, whose crops were undamaged, actually profited by the freeze. Trees in many groves were severely damaged, and in a few cases entire orchards were frozen to the ground.

Costs of replacing valuable orchards which were destroyed and rehabilitating orchards frozen back almost to the tree trunks also are very difficult to estimate.

Damage in general was astonishingly slight, considering the temperatures and low temperature durations. Damage to fruit was 20 percent less than in 1922 and tree damage also was much smaller, despite the fact that the 1922 freeze was much less severe in all respects. Reasons for the smaller amount of damage in 1937 than in 1922 are obvious. The tremendous increase in acreage equipped with orchard heaters since 1922 and the much greater efficiency with which frost protection operations were handled were undoubtedly the greatest factors. Effects of "mass heating" also were very important. Unprotected orchards located to leeward of heavily fired groves received much benefit from drifting heated gases, and all unprotected groves located in areas in which more than 70 percent of the acreage was equipped with heaters received a large amount of protection. In many cases such groves showed no damage to trees or fruit following the freeze. It is believed the heavy orchard heater smoke, which covered most of southern California throughout the duration of both freezes, materially reduced the amount of damage through shading trees and fruit from the sun during the day. This conclusion is based entirely on observation, but there has been much evidence during the past 25 years to support it.

Weather preceding the 1922 freeze was warm both day and night, with frequent warm showers, making both trees and fruit particularly susceptible to low-temperature damage. Following the 1922 freeze the sky was clear, with bright sunshine, and day temperatures rose quickly to 75°. Damaged fruit began to drop from the trees within two days after the freeze had ended, and damaged foliage quickly curled and dried.

During December 1936, on the other hand, frequent light to moderate frosts hardened trees and fruit. Day temperatures were unusually low, remaining below 60° at Pomona from December 23 to the end of January. There was much cloudy weather, with frequent rains, which slowed tree growth. Cold rains immediately following the freezes appeared particularly to benefit trees whose foliage had curled badly and gave every indication of losing all their leaves. In contrast to the extremely unfavorable weather before and after the 1922 freeze, the weather which preceded and followed the two freezes of January 1937 could hardly have been more favorable.

Damage caused by the 1937 freeze was of course not confined to oranges, lemons, and grapefruit. Practically all the lime trees in the State were completely defoliated and many were killed. A large percentage of the avocado acreage suffered heavy foliage damage, and the crop was reduced by 33 percent. The stems of mature avocados were frozen in many cases with little or no damage to the fruit, but weakening of the stems caused the fruit to fall from the trees, resulting in a flood of fruit which had to be marketed immediately after the freezes had passed.

The cut flower industry of southern California, which normally ships from 6 to 13 carloads of flowers per day, suffered a loss of \$200,000 due to the cold. Loss to winter truck crops of the State was estimated at approximately \$2,000,000. California normally ships about 500 carloads of vegetables per day during the winter months. Following the freezes not only were shipments cut off, but it became necessary to import vegetables into the State from Mexico and Florida to supply local demand. Prices of fresh vegetables increased from 50 to 100 percent, and prices of canned vegetables also advanced sharply. All

subtropical nursery stock suffered severe damage except where given adequate protection against low temperatures.

The pouring of concrete in the open was discontinued during the coldest periods, and many calls for forecasts were received from contractors, both in person and by telephone.

GENERAL ASPECTS OF THE FREEZE

The spectacle of thousands of orchardists fighting to prevent the loss of practically everything they owned, aided by every agency both public and private that could possibly be of assistance, baffles description. The most intensive fight was waged to secure fuel to keep the orchard heaters burning.

Railroad companies had a very vital interest, almost as deep as the growers themselves, in preventing damage to trees and crops, since much of their annual revenue comes from the movement of the fruit. On the strength of the first warning of impending cold, before the arrival of the freeze, one railroad company began to bring tank cars of every description from all parts of its line into southern California. More than a hundred cars which had been used to transport coconut oil were rushed south from the San Francisco Bay region. Cars which had been used to carry gasoline, molasses, alcohol, road oil, and even fish oil were concentrated in southern California for the movement of orchard heater oil. There was no time for cleaning the cars, and many a gallon of molasses was burned in the heaters during the freeze. Delivery of cars to the great number of destinations in the citrus districts involved large scale switching operations, necessitating a large number of trains. At times as many as a dozen oil trains operated simultaneously along a 50-mile railway line. In order to simplify operations and minimize confusion, all tank cars were pooled by the railroads, regardless of ownership.

All railroad crews in southern and central California were pressed into service, and as the fuel shortage became more acute additional crews were brought in from as far east as Texas and as far north as San Francisco. Train crews were worked the legal limit of 16 hours, given 8 hours rest at whatever point they happened to be located, and put back to work. Movement of every other type of freight except the most perishable was subordinated to movement of oil. For several days at a time oil was moved almost exclusively. Near the end of the second freeze the railroads notified the citrus growers that their own supplies of oil for locomotive fuel were practically exhausted and the cars would have to be diverted to their own use if rail operations were to continue. Orchard heater oil transported by rail during the freeze period totaled 4,435 12,000-gallon carloads. At one time unfilled orders for more than 1,500 carloads of oil were on file at the cooperative purchasing agency of the California Fruit Growers Exchange alone.

Motor tank trucks were similarly mobilized before the freeze, many being brought to southern California from points 500 miles distant. Trucks were pressed into service which had been used to haul such commodities as honey, cider, and even oil-well mud. Junk yards were combed for any tank trucks which could move under their own power, and permission was granted by the State to operate them without license plates. Trucks were lined up for more than a mile at loading points. Ice companies, milk distributors, and automobile truck dealers all cooperated in moving oil to groves. Fuel transportation continued with feverish speed both day and night. County road crews were kept busy sanding roads which had become

slippery with spilled oil. Caravans of oil trucks were convoyed at full speed by highway traffic officers from oil refineries to citrus districts, where they scattered to grope their way through the heavy smoke to their various orchard destinations. Disputes over oil deliveries, and ownership of oil in community tanks were numerous and resulted in many court suits later.

Diversion of trucks to orchard-heater fuel service interfered seriously with fuel-oil delivery for heating buildings, and guests shivered in many a large hotel and apartment building. Development of the heaviest demand for natural gas ever experienced made it necessary to curtail supplies for industrial use and many factories were forced to close temporarily. Laundries were particularly hard hit, due to the tremendous increase in volume of business caused by the smoke and soot, and the difficulty in keeping fabrics clean after laundering, as well as the shortage of gas for plant operation.

Discarded automobile tires were brought in from increasingly-distant points for orchard heater fuel, and the price rose steadily from 10 dollars per ton at the beginning of the freeze to 50 dollars per ton near the end. In some cases growers, unable to secure orchard heater oil, bought up all the kerosene obtainable in their vicinity and burned it in their heaters. One grower, unable to maintain a satisfactory temperature in his grove with his heaters, burned additional oil poured into holescooped in the frozen ground.

The orchard heater fuel situation was desperate in many localities on the night of January 23. In the Redlands district oil was available for only one-half the heaters during the day and storage tanks were dry. The arrival of a trainload of oil at 9 p. m. was too late for a few groves but averted disaster in most cases.

Irrigation water, poured into orchards during the second freeze in the hope that it would lessen crop damage, froze rapidly, and was still solidly frozen 4 days later. Fish ponds and other still water remained solidly frozen throughout both freeze periods, and the Santa Ana River, reduced to creek size by diversion for irrigation, was completely frozen on January 24. Icy streets and highways, heretofore unknown in southern California, created serious traffic hazards. Falls on icy sidewalks caused many injuries. In Los Angeles a can of milk fell from a truck and the milk froze on the street car tracks, causing a wreck which injured 14 passengers. Water pipes froze in many southern California cities, and in one citrus belt town two trucks were kept busy turning off water at residence meters to prevent damage. In the Imperial Valley stock went without water because of heavy ice forming on watering troughs, and repair shops reported more than 100 tractor and 200 automobile radiators damaged by freezing. At Oroville, in the Sacramento Valley, ice thick enough for skating formed on the Feather River and remained for several days.

The fight to supply fuel to the orchards and to keep heaters burning to save the crops took place under a thick black canopy of orchard-heater smoke, so heavy that it started operation of automatic fog horns at Los Angeles harbor and necessitated the burning of street lights in some citrus belt cities until after noon. In some localities heaters were lighted at 4:30 p. m. and were not extinguished until 12:30 p. m. on the following day.

Fruit growers, including retired professors, physicians and business men, unshaven and incredibly dirty, did not leave their orchards in some cases for 3 days and nights, having their meals brought to them and eating while they worked. Considering the age and state of health of many

of the growers, there were surprisingly few deaths from over-exertion and exposure. Outstanding was the loyalty of the men hired to handle the firing and filling of the heaters. The battle to save the crop seemed to imbue them with the same spirit they might have had if they were defending their own homes against an invading army. In some cases firing crews recruited at the beginning of the freeze, personally unknown to the grower, worked doggedly day and night without supervision when the grower became suddenly ill. Hired men often worked 45 consecutive hours without sleep. A few were removed to hospitals when they collapsed due to physical exhaustion.

It was impossible to fill the heaters without spilling oil, and many laborers worked in oil saturated clothing. Oil covered limbs were rubbed raw in the process of carrying buckets of oil to fill heaters. Shivering men stopped a moment to warm themselves at a burning heater and were burned to death or suffered serious injury when their oil-soaked clothing ignited. Explosion of heaters during refilling operations was responsible for other serious injuries. Strangely enough, filling of heaters while still burning proved to be a safe operation. Explosions occurred in filling heaters which supposedly had been extinguished, but which contained smoldering soot which ignited gases. Traffic accidents were frequent due to the heavy smoke.

Many fore-sighted growers avoided accidents to orchard workers by requiring every employee to change clothing after filling heaters, and insisting that no heaters be filled until they had been lighted. The manager of one large orchard purchased 200 pairs of overalls for his men at the beginning of the freeze, all that could be obtained in a citrus belt city. In one 48-hour period more than 200 gallons of coffee were served to the men on this one ranch.

Schools were closed generally in citrus belt cities during the freezes due to the heavy smoke and the difficulty in keeping buildings warm, and also because a large proportion of the students were needed at home to assist in the battle to save the groves. Many stores were closed "for the duration of the African fog." In other stores merchandise which might be damaged by smoke was kept under heavy canvas covers and shown only on request. Housewives covered their furniture, removed drapes and curtains, and in some cases sealed doors and windows with tape.

The strain on everyone connected with the citrus industry, from the growers to the heads of marketing organizations, was terrific throughout the progress of the two freezes. The cold and the all-pervading smoke made the life of the ordinary citizen unpleasant, but it was not until the freeze had passed that a spirit of sympathy and cooperation changed in a few localities to criticism and complaint.

As usual in such crises, a few people with no practical knowledge of meteorology or orchard heating hastened to give their views to the newspapers, adding to the confusion and increasing the difficulties of the harassed growers. One newspaper article ascribed the low temperatures to orchard heater smoke and stated there would have been no freeze without smoke. In districts where the smoke was heaviest it unquestionably interfered with the normal morning rise in temperature, but a comparison of temperature records from the smokiest areas with those obtained in districts where there was no orchard heating and no smoke at any time proves definitely that the effect on the maximum temperature of the day was almost negligible. The absurdity of the argument is further demonstrated by the fact that the lowest temperatures in any of the citrus districts occurred in sections where

there was no smoke; in fact, the records show that minimum temperatures in unheated groves in the smokiest areas were much higher than they would have been if there had been no orchard heating. The great quantities of frigid air pouring into southern California throughout the freeze periods, and the fact that the morning rise in temperature is slower and begins later when the ground surface is frozen were entirely ignored. Minimum temperatures in the Imperial Valley, where there was no heating and no smoke, normally are the same as or higher than those in the Pomona district, where more than 80 percent of the groves are equipped with heaters, during moderately cold periods with little heating at Pomona. The lowest temperature registered in the Pomona district during the freeze was 20.5° F., at a station farthest from any orchard heating operations, while the lowest temperature in the Imperial Valley was 12° F. Generally speaking, the normally coldest areas were warmest during the freeze, due to the greater concentration of heating equipment.

Another published article stated, "If the temperature does not increase rapidly with altitude and does not reach 32°, heating is futile." If this statement were true, orchard heating would have been futile throughout most of the citrus districts of the State during the coldest nights of the freeze. It is true that the protection of lemons in the Sacramento Valley proved impractical with standard orchard heating equipment during the second freeze when the temperature fell to 15° F. accompanied by a strong wind, but more than half the crop was carried through the first freeze without damage, with outside temperature of 22.5° F. accompanied by a strong wind, and 15.5° F. without wind. In Tulare County there was loss of lemons and some lemon tree damage in isolated groves equipped with heaters, when the temperature dropped to 14° F. In all cases, however, in which standard heating equipment was properly used the contrast between heated and unheated groves was very marked.

In southern California heating was uniformly effective in groves with standard equipment efficiently handled, although there was some damage in groves with too small a number of heaters to the acre. Temperatures over large areas were held hour after hour at 28° F. with outside temperatures of 19° F. In normally cold districts with a high percentage of the total acreage equipped with heaters, there was little or no damage in groves not equipped with heaters. Lowest temperatures were registered in nearly all cases at stations located farthest from heated sections.

Growers have been urged for many years to "stagger" their orchard heaters in the groves, i. e., to place heaters in every row rather than to concentrate them in alternate rows. Soundness of this advice was amply demonstrated during the 1937 freeze, as it had been in previous freeze years, by the damaged fruit in the "dark" rows. There is no questioning the fact that radiation of heat directly from the heaters to the trees and fruit plays an extremely

important part in orchard heater protection, especially during nights with wind and little or no temperature inversion near the ground. Since this influence does not appear in sheltered thermometer readings, the grower is likely to underestimate the effectiveness of his orchard heating operations under freeze conditions.

The amount of orchard heater oil consumed during the freezes has been estimated all the way from 82,000,000 gallons, costing \$4,000,000 in the heaters, to 100,000,000 gallons, costing \$5,000,000. Costs of operating the heaters varied so greatly that estimates are of little value. Estimates of \$10,000,000 for fuel and labor have been generally accepted as approximately correct.

The strike which tied up many ships on the Pacific Ocean handicapped forecasting during the freezes, but resulted in an accumulation of diesel oil due to lack of demand for ship fuel, without which orchard heater fuel would have been completely exhausted before the end of the second freeze.

Experience gained during the freezes has resulted in the installation of many new oil-storage tanks in the orchard districts, and the enlargement of loading racks to handle the filling of a larger number of trucks simultaneously. The type and amount of orchard-heating equipment needed to render adequate protection to crops under extreme conditions has been indicated definitely. The fact that trees and fruit can be protected against extremely low temperatures, with little or no temperature inversion near the ground has again been demonstrated.

After the excitement of fighting the freezes had passed and the orchards and the major portion of the crop had been saved, a great hue and cry arose over the smoke nuisance. Several citrus belt counties passed ordinances limiting the output of smoke per heater in a given period of time. Inventors brought forth dozens of new heater designs, practically all of them without practical value. As a matter of fact, practical men have been working constantly during the past 20 years to improve the combustion of orchard heaters, and radical improvement appears very unlikely considering the rigid limitations of cost which the grower is able to bear. Equipment now in use can be made to consume a good grade of diesel oil with very little smoke per heater, but even if the smoke output of every heater were cut to the minimum, the simultaneous burning of the 4,000,000 units in use would still create an objectionable amount. Burning of heaters with a minimum of smoke requires use of clean oil and thorough cleaning of burners at frequent intervals. Growers seldom take time to clean equipment even in ordinary winters, and under freeze conditions such as those of 1937 cleaning is practically out of the question. Oil quality also deteriorates under such emergencies. If the general public insists on smokeless skies when the next freeze occurs, it undoubtedly will have to be at the cost of a tremendous loss to the citrus industry, and indirectly to the public, both in California and throughout the Nation.